FROM THE ICE TO THE OPEN OCEAN

~THREATS TO PHYTOPLANKTON PRODUCTIVITY IN THE ANTARCTIC MARINE ECOSYSTEM FROM A CHANGING CLIMATE~

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Certificate of Authorship/Originality

I certify that the work presented in this thesis and the research to which it pertains, are the product of my own work and to the best of my knowledge, original. Any quotations, ideas or work conducted by others, published or otherwise, are fully acknowledged in accordance with the standard referencing practices of the discipline. Co-authors of published, submitted papers or articles in preparation have been acknowledged for their contributions and for each publication herein my personal contribution and role clearly described. Furthermore, I certify that this thesis has not previously been submitted, in whole or in part, for a degree at this or any other university.

Signed____________________________________

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CSIRO

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And now there came both mist and snow,
And it grew wondrous cold:
And ice, mast-high, came floating by,
As green as emerald.

And through the drifts the snowy clifts
Did send a dismal sheen:
Nor shapes of men nor beasts we ken –
The ice was all between.

The ice was here, the ice was there,
The ice was all around:
It cracked and growled, and roared and howled,
Like noises in a swound!

Samuel Taylor Coleridge
The Rime of the Ancient Mariner

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"The sea, once it casts its spell, holds one in its net of wonder forever."

Jacque Cousteau

1 SUMMARY

1 Summary

The Antarctic marine ecosystem is unique and dynamic, changing seasonally and forming specialised niche habitats including open ocean, sea ice and meltwater environments. Phytoplankton are key species in the structure and function of the Antarctic ecosystem, instrumental in the regions biogeochemistry, fundamental to the food web and strong contributors to global primary production and carbon sequestration. Understanding the photosynthetic plasticity of Antarctic phytoplankton is essential to understanding the effects global change is likely to have on primary production in the region. Through a series of experiments, this thesis explores the processes of light acclimation, photoprotection and photoinhibition in Antarctic microalgae under different environmental stressors, comparing photophysiological responses of species known to inhabit the sea-ice, meltwater and pelagic regions of Antarctic waters.

The photosynthetic properties of three Antarctic diatoms (*Fragilariopsis cylindrus*, *Pseudo-nitzschia subcurvata* and *Chaetoceros* sp.) to changes in salinity, temperature and light were compared. Large heterogeneities in the photoprotective capacity of the three species and several distinct physiological strategies in response to the rapid changes in the ambient environment were observed (Publication I). Similarly, photosynthesis and net primary productivity was species-specific with large differences between environmental conditions (Publication II). Fast induction kinetics and pulse amplitude modulated fluorometry were used to demonstrate high levels of flexibility in light acclimation capabilities of sea ice algae from the east Antarctic. Inhibitors and pigment analyses identified xanthophyll cycling as the critical mechanism for photoprotection and preferred means by which sea ice diatoms regulated energy flow to PSI (Publication III). While immunoblot analyses of natural communities measured minimal D1 protein breakdown in algae exposed to irradiances up to 200 μmol photons m^{-2} s^{-1}. These data showed that sea ice diatoms had low intrinsic susceptibility to PSII photoinactivation and strong irradiance-dependent induction of non-photochemical quenching that was independent of protein re-synthesis (Publication IV).

The remaining chapters investigated photoprotective strategies and photosynthetic plasticity of phytoplankton under nutrient limitation. Nitrogen depletion in *F. cylindrus* had a strong influence on non-photochemical quenching capacity and resulted in the impairment of photosynthetic electron transport resulting in the formation of Q_B non-reducing PSII centres within the photosystem (Publication V). The influence of iron-limitation and high light stress on the growth and physiology of Southern Ocean phytoplankton revealed a community-based response of measurable changes in pigment ratios, photosynthetic capacity and community composition (Publication VI). Iron-limited phytoplankton altered the allocation of photosynthetically derived energy, increasing photoprotective pigment pools and down-regulating photochemistry, at the expense of photosynthetic plasticity.